Computational Analysis of Artificial Gravity as a Possible Countermeasure to Spaceflight Induced Bone Loss

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During exploration class missions, such as to asteroids and Mars, astronauts will be exposed to reduced gravity for extended periods. Data has shown that astronauts lose bone mass at a rate of 1% to 2% a month in microgravity, particularly in lower extremities such as the proximal femur. Exercise countermeasures have not completely eliminated bone loss from long duration spaceflight missions, which leaves astronauts susceptible to early onset osteoporosis and greater risk of fracture. Introduction of the Advanced Resistive Exercise Device and other large exercise devices on the International Space Station (ISS), coupled with improved nutrition, has further minimized bone loss. However, unlike the ISS, exploration vehicles will have very limited volume and power available to accommodate such capabilities. Therefore, novel concepts like artificial gravity systems are being explored as a means to provide sufficient load stimulus to the musculoskeletal system to mitigate bone changes that may lead to early onset osteoporosis and increased risk of fracture. Currently, there is minimal data available to drive further research and development efforts to appropriately explore such options. Computational modeling can be leveraged to gain insight on the level of osteoprotection that may be achieved using artificial gravity produced by a spinning spacecraft or centrifuge. With this in mind, NASA's Digital Astronaut Project (DAP) has developed a bone remodeling model that has been validated for predicting volumetric bone mineral density (vBMD) changes of trabecular and cortical bone both for gravitational unloading condition and the equivalent of 1g daily load stimulus. Using this model, it is possible to simulate vBMD changes in trabecular and cortical bone under different gravity conditions. In this presentation, we will discuss our preliminary findings regarding if and how artificial gravity may be used to mitigate spaceflight induced bone loss.